Sensory Irritation of Select Experimental Photochemical Oxidants

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ABSTRACT

Groups of male Swiss-Webster mice were exposed to photochemical oxidant mixtures generated by reacting various hydrocarbons with nitrogen dioxide in the presence of ultraviolet light while their respiratory rates were monitored. The hydrocarbons used were 1,3-butadiene, 1-butene, *cis*-2-butene, ethylene, propylene, *n*-butane, and ethane. The initial hydrocarbon concentrations ranged from .4 to 18 ppm, with the initial nitrogen dioxide concentration being one-third that of the initial hydrocarbon concentration. New groups (four mice per group) were exposed for 5 min at 0, 1, 2, 3, and 4 hr of ultraviolet irradiation. Dose-response curves for each hydrocarbon were developed by plotting the maximum percent decrease in respiratory rate observed during the 4 hr of irradiation of each mixture as a function of the initial hydrocarbon concentration present. The percent decrease in respiratory rate in mice was chosen as an index of the sensory irritation of the upper respiratory tract for each mixture. The results showed that the potency of the photochemical oxidant mixtures generated from the hydrocarbons to be propylene > 1, 3,-butadiene = 1-butene = *cis*-2-butene > ethylene. When ethane or *n*-butane was used, no decrease in respiratory rate was observed. These results are compatible with the data obtained in human volunteer studies. Guidelines for relating the percent decrease in respiratory rate in mice to human reactions are presented.

PHOTOCHEMICAL OXIDANTS are a problem of increasing concern in many urban areas. They are produced by the action of sunlight on hydrocarbons and oxides of nitrogen, released primarily from vehicular emissions, present in the atmosphere. The products of these photochemical reactions cause sensory irritation in humans, characterized by burning of the eyes, nose, and throat.

Previous studies on sensory irritation caused by photochemical oxidants have used human volunteers. Volunteers in these experiments were exposed to photochemical oxidant mixtures and asked to indicate both the severity of the sensory irritation and rapidity of onset.[1-22] It was decided to attempt to develop an animal model system to evaluate the sensory irritation of photochemical-oxidant mixtures. There are many advantages to an animal model system, since higher concentrations and longer exposure times can be used and unknown mixtures can be evaluated without risk.

The parameter chosen to be monitored in this animal system is the characteristic reflex decrease in respiratory rate that is seen in numerous species (e. g., cat, rabbit, dog, guinea pig, mouse, and man) when exposed to a sensory irritant.[23] By measuring this reflex (as percent decrease in respiratory rate) while exposing mice to various concentrations of photochemical oxidant mixtures, dose-response curves can be obtained. The photochemical oxidant mixtures are generated by reacting hydrocarbons and nitrogen dioxide (NO_2) in the presence of an ultraviolet light.

The series of experiments presented here evaluate seven hydrocarbons used to generate the photochemical oxidant mixture. These results are also compared to published data on human volunteer exposure to similar mixtures.[1-5]

Materials and Methods

Animals

The animals used in this study were outbred-Specific Pathogen-Free, male Swiss-Webster mice, weighing between 25 and 35 g. New groups of four mice were used for each exposure.

Gases

Propylene, 1-butene, *cis*-2-butene, *n*-butane, ethylene, and ethane (all 99% minimum purity) and NO_2 (95.5%) were obtained from Matheson Gas Products; 1, 3,-butadiene (99.5%) was obtained from Air Products Inc.

Photochemical Oxidant Generating Chamber

The hydrocarbons and NO_2 were reacted in a 101 liter glass, stainless steel, polytetrafluoroethylene chamber (Fig. 1). The pure reactant gases were introduced into the chamber via a rubber septum, using a gas-tight microsyringe. The chamber contained a 61-cm, G.E. F20T12/BL 20-watt blacklight. During the 4-hr experiment, the temperature rose from 22°C to 30°C. The air was continuously circulated by a pump, and passed through an infrared analyzer.

Monitoring of Hydrocarbons

The air from the generating chamber was passed through an in-line Miran infrared analyzer in order to confirm the initial hydrocarbon concentration and monitor the hydrocarbon decrease as the reactions progressed. The air was then directed back to the generating chamber or to the exposure chamber.

Exposure Chamber

The animal exposure chamber used in these experiments is also shown in Figure 1. It was constructed entirely of glass, and had an internal volume of 2.3 l. The body of each animal was held in a plethysmograph, sealed with a rubber stopper. The head of each animal extended into the exposure chamber, through a rubber latex dam around its neck, which provided an air-tight seal. The animals were placed in the chamber, and the chamber was connected to the airflow from the generating chamber.

Measurement and Evaluation of Respiratory Rate

Each of the four plethysmographs of the mouse exposure chamber was connected to a pressure transducer. As each mouse inhaled, a positive pressure was created in the plethysmograph, and as the mouse exhaled, a negative pressure resulted. These pressure changes were sensed by the pressure transducers. The resulting signals were then amplified and displayed on a four-channel oscillograph. A typical response is shown in Figure 2.

The respiratory cycle was seen in two phases: an upward defelection on the oscillograph tracing represented the inspiratory phase, and a downward deflection denoted the expiratory phase. When an animal inhaled a sensory irritant, the upward deflection remained rapid, but a characteristic pause was seen in the downward deflection. This indicated that while the inspiratory phase was unchanged, the animal was holding its breath after inspiration, and therefore, was decreasing its respiratory rate. The use of the four-channel oscillograph allowed for continuous monitoring of each animal during the experiment.

The signals going to the four oscillograph channels were also recorded on a four-channel tape recorder. Upon completion of the experiment, each channel of the tape was fed into a frequency-to-voltage converter, whose outputs were averaged and displayed on a single-channel oscillograph. This display was the averaged respiratory rate of the four animals. A typical output is shown in Figure 3.

A control level was first established, during which the animals were exposed to fresh air. When each animal was exposed to the airborne sensory irritants, its respiratory rate decreased to a plateau, and remained at this level until the end of the exposure. After the exposure to the sensory irritant mixture, the animals were monitored while they recovered, during which time they breathed fresh air. During recovery each animal was seen to return to its control respiratory rate. For each experiment, the percent decrease in respiratory rate from the control was then calculated.

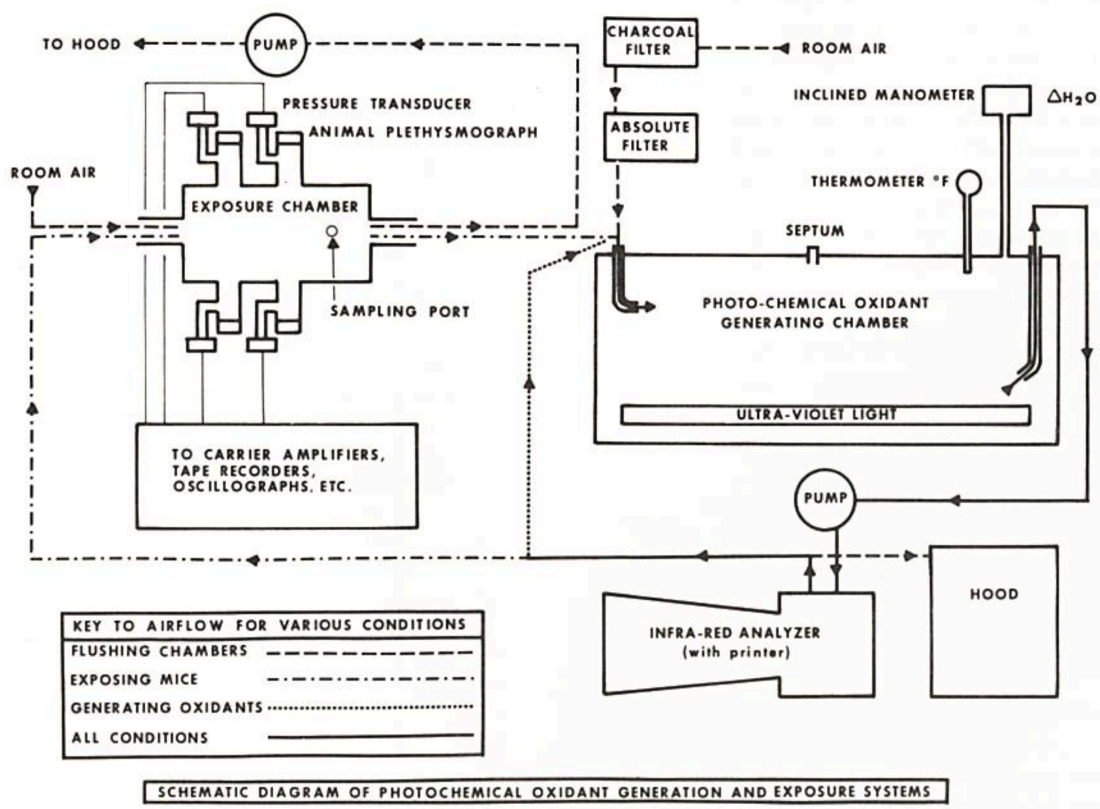

Fig. 1. Schematic diagram of photochemical oxidant generation system and exposure chamber. In a typical experiment the irradiation chamber is flushed by filtered air before introducing the hydrocarbon and nitrogen dioxide gases, and then recirculation of the mixture is initiated with continuous monitoring by the infrared analyzer. Every hour, for 4 hr, the exposure chamber is connected to the recirculation system for a period of 5 min to observe the reaction of the animals. The animal exposure chamber is also equipped with a pumping system for room air flushing before and after exposure to the irradiated mixture. A dilution factor (< 2%) occurs every time the animal chamber is connected to the recirculating system of the irradiation chamber.

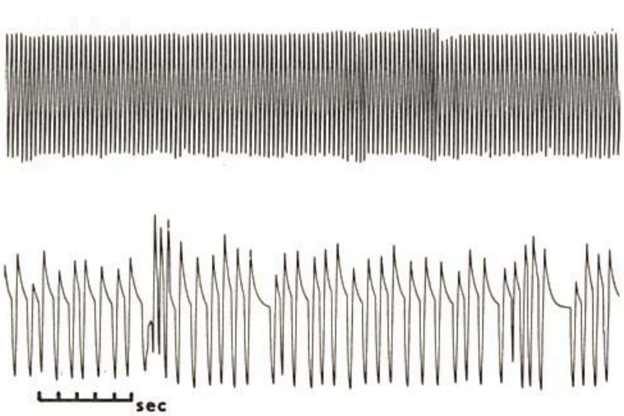

Fig. 2. Typical oscillograph display showing the respiratory cycle for control conditions in the upper tracing and exposure to sensory irritants in the lower tracing. The upward deflection represents the inhalation phase and the downward deflection the exhalation phase. The inhalation phase is rapid during both control and exposure conditions. During response, the exhalation phase is extended and shows a characteristic pause.

Potency-Response Curves

Since formation of sensory irritants is a dynamic process, it was necessary to determine when during the 4 hr of irradiation a maximum effect would be seen for each hydrocarbon/NO_2 mixture. The following sequence was followed for these experiments. The hydrocarbon and NO_2 gases were introduced into the chamber and allowed to mix while the room air-control respiratory rates for the mice were recorded. The animal exposure chamber was then connected to the generating chamber while the exposure respiratory rates were monitored. At the end of the 5-min exposure the mouse exposure chamber was disconnected, the ultraviolet light turned on, and the mixture continuously circulated. This procedure provided for minimal mixture loss and dilution over the 4-hr experiment.

At hourly intervals during the 4 hr, a new group of four mice was exposed to the reacting mixture for a period of 5 min while their respiratory rates were monitored. Thus, each group of four mice was used once.

High hydrocarbon concentrations were chosen to facilitate identification of the time of irradiation at which maximal response would occur. Time-potency curves were developed from these data by plotting the potency as percent decrease in respiratory rate as a function of the ultraviolet irradiation time.

Tracheal Cannulation

In order to demonstrate that the observed respiratory rate decreases were caused by sensory irritation of the upper upper respiratory tract, groups of mice were exposed while breathing through a tracheal cannula. Anesthesia for tracheal cannulation was achieved with 60 mg/kg of ketamine hydrochloride and 64 mg/kg of acepromazine maleate administered intramuscularly. Uncannulated, anesthetized mice served as controls. The initial hydrocarbon concentrations used for this series of experiments were those expected to produce approximately 50% decrease in respiratory rate in normal control mice.

Dose-Response Curves

A dose-response curve was developed for each hydrocarbon that produced sensory irritation. The data for each dose-response curve were obtained by varying the initial hydrocarbon concentration present in the generating chamber, while always maintaining the NO_2 concentration at one-third the hydrocarbon concentration. This 3/1 hydrocarbon/NO_2 concentration ratio has been shown to result in a maximal sensory irritation in humans.[24]

Mice were exposed to the mixture, and their respiratory rates monitored according to the procedural sequence described above.

For each dose-response curve, the maximum percent decrease in respiratory rate is plotted as a function of the logarithm of the initial hydrocarbon concentration for that mixture.

Results

From the sample time-potency curves (Fig. 4) it is obvious that for 1,3-butadiene, 1-butene, and *cis*-2-butene, the maximum percent decrease in respiratory rate occurred between 2 and 3 hr of ultraviolet irradiation. For propylene and ethylene, the maximum potency did not occur until 4 hr. The curves shown in Figure 4 were those developed at the highest hydrocarbon concentrations; comparable results were obtained at the lower concentrations, but lower in magnitude.

The results of the experiments in which the mice were exposed via a tracheal cannula clearly showed that the site of the reactions that provoke the decrease in respiratory rate is the upper respiratory tract. For the five hydrocarbons tested (1, 3-butadiene, 1-butene, *cis*-2-butene, ethylene, and propylene), anesthetized, uncannulated mice all showed

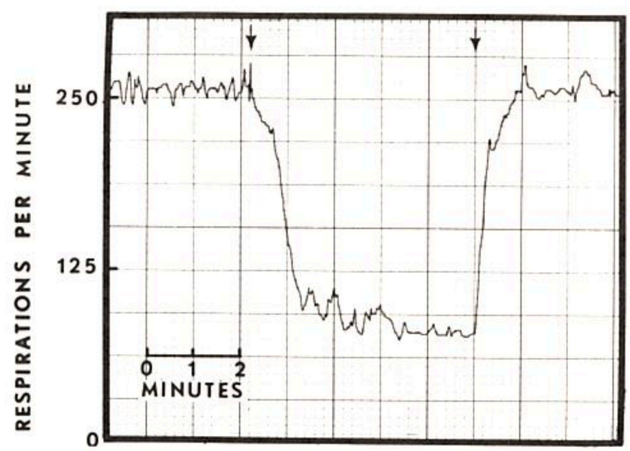

Fig. 3. Typical oscillograph display of the averaged respiratory rate of four mice during an experiment. The two arrows indicate the beginning and end of the exposure period. This output was obtained for 3 hr irradiation of a mixture that initially contained 18 ppm of 1, 3-butadiene and 6 ppm of NO_2. The control period immediately proceeds the exposure and the recovery immediately follows it.

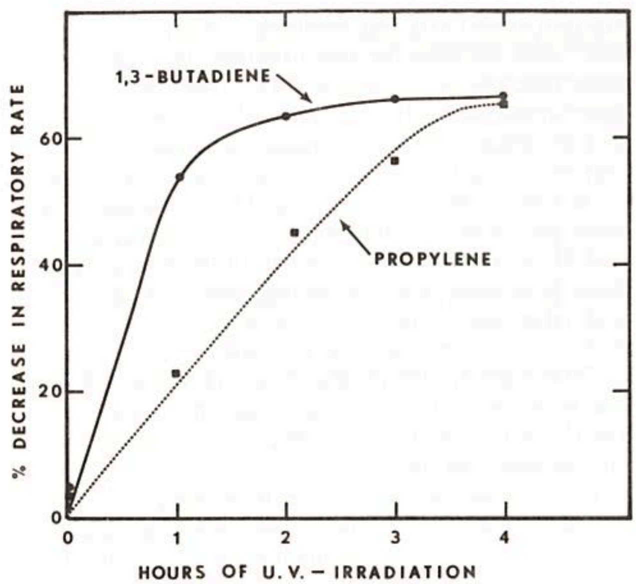

Fig. 4. Time-potency curves. The average percent decrease in respiratory rate for four mice reached during the 5-min exposure is shown as a function of ultraviolet irradiation time for 1, 3-butadiene and propylene in the presence of NO_2. Propylene and ethylene showed the same pattern. *Cis*-2-butene and 1-butene showed the same pattern as 1, 3-butadiene. All data points are significantly different ($P < .05$) from control except at time zero.

the expected 38 to 54% decrease in respiratory rate. No decrease in respiratory rate was observed for any of the cannulated anesthetized mice exposed to the same mixtures.

The dose-response curves for 1, 3-butadiene, 1-butene, *cis*-2-butene, ethylene, and propylene are shown in Figure 5.

Each curve shows a linear relationship between the logarithm of the initial hydrocarbon concentration and the response. The lines drawn represent the lines obtained by the least squares linear regression analyses.[25]

Even at initial concentrations as high as 18 ppm no decrease in respiratory rate was observed when the animals were exposed to ethane or *n*-butane. Thus, no dose-response curves are presented. Similarly, no decrease in respiratory rate was seen when animals were exposed to nonirradiated mixtures of any of the seven hydrocarbons—even at concentrations as much as 18 ppm (and 6 ppm NO_2).

Of the three hydrocarbons that caused maximal decreases in respiratory rate at 2 hr, 1, 3-butadiene and 1-butene have essentially the same dose-response curve. The dose-response curve for *cis*-2-butene is very similar. The curve for ethylene is markedly shifted to the right of those for 1, 3-butadiene, 1-butene, and *cis*-2-butene. The curve for propylene is markedly shifted to the left.

From these curves, the initial hydrocarbon concentration associated with any specific percent decrease in respiratory rate can readily be calculated from the linear regression. For purposes of comparison and extrapolation to human data, the initial hydrocarbon concentration associated with a 50% decrease in respiratory rate is chosen and termed RD_{50}. The RD_{50}s and 95% confidence limits for the five hydrocarbon/NO_2 are indicated on the dose-response curves (Fig. 5) and tabulated in Table 1.

Upon inspection of the curves it seems obvious that 1, 3-butadiene, 1-butene, and *cis*-2-butene are quite similar in their dose-response patterns, having apparently equivalent slopes and RD_{50} values. Using 1, 3-butadiene as the standard, the other four- and two-carbon curves were compared to it to test for equal slopes and RD_{50} values.[25] This analysis showed that the slopes of the 1-butene and *cis*-2-butene curves are not significantly different from that for 1, 3-butadiene, but the slope of the ethylene curve is ($P < .01$). Also, the RD_{50} values for 1-butene and *cis*-2-butene lie within the 95% confidence interval for the RD_{50} of 1, 3-butadiene, while that for ethylene does not.

The above results suggest that 1-butene and *cis*-2-butene be grouped with 1, 3-butadiene as strongly irritating, ethylene be considered as moderately irritating, and *n*-butane and ethane as nonirritating.

The difference in behavior of the propylene mixtures and the markedly greater responses suggest that propylene be considered separately.

Discussion

The RD_{50} concentration levels provide a convenient point for comparing the various hydrocarbons used to generate photochemical oxidant mixtures. Table 1 provides a ranking of the hydrocarbons in terms of their potency to decrease respiratory rate due to sensory irritation.

In order to evaluate these data in terms of human experience it is necessary to relate the measured parameter, per cent decrease in mouse respiratory rate, to the human response of sensory irritation associated with a burning sensation of the eyes, nose, and throat. It has been demonstrated that the decrease in respiratory rate is due to the effect of airborne chemicals on the upper respiratory tract.[23,26] Furthermore, it has been shown that airborne chemicals causing a decrease in respiratory rate in mice

Table 1.—Sensory Irritation Potency of Hydrocarbon Mixtures

Hydrocarbon	RD_{50}* (ppm)	95% Confidence Limit
Propylene	1.5	1.1 - 2.0
1, 3-Butadiene	7.65	5.46 - 10.72
1-Butene	7.78	5.03 - 12.0
cis-2-butene	10.7	6.39 - 17.8
Ethylene	14.9	14.7 - 15.0
n-butane	†	--
Ethane	†	--

*RD_{50} = concentration associated with a 50% decrease in respiratory rate, calculated from the dose-response curves.
†No significant decrease in respiratory rate observed, thus no dose-response relationship existed.

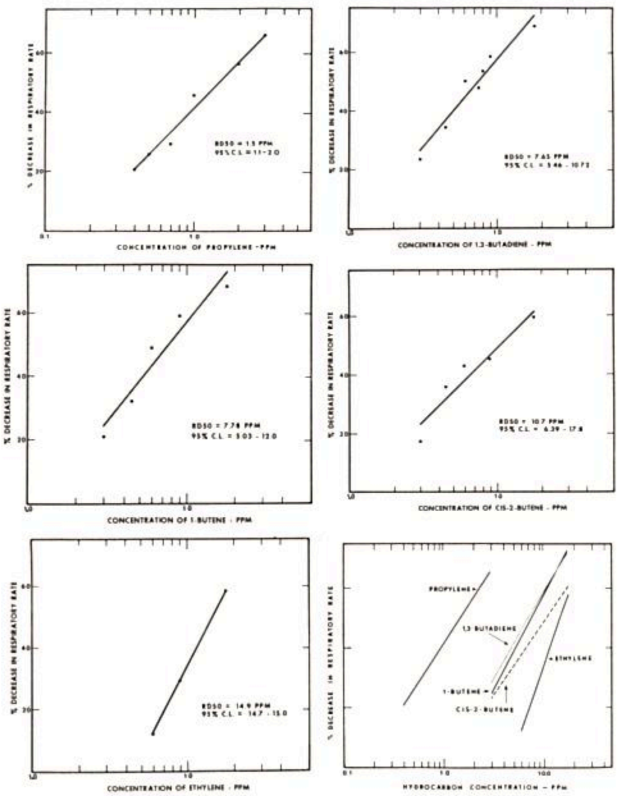

Fig. 5. Dose-response curve for each of the hydrocarbons tested. Each point represents the maximum percent decrease in respiratory rate that occurred during a 5-min exposure to an ultraviolet irradiated mixture that contained the initial hydrocarbon concentration indicated. The initial NO_2 concentration was 1/3 the HC concentration. No dose-response relationship was seen for *n*-butane or ethane.

elicit a sensory irritation response in man characterized by a typical burning sensation of the eyes, nose, and throat.[23]

Previous studies in this laboratory have developed mouse dose-response curves for nine sensory irritants.[29] Combined with a review of the scientific literature, it has been shown that a relationship exists between the RD_{50} obtained in mice and the human response.[28,29] This relationship allows for the prediction of human response to specific concentrations of a sensory irritant, namely: (*a*) at RD_{50} a sensory irritation of the eyes, nose, and throat would be evoked in man and would be rapidly incapacitating; (*b*) at 1/10 RD_{50} a slight sensory irritation response would be evoked, but would be tolerable; and (*c*) at 1/100 RD_{50} a minimal response or no response would be evoked.

These relationships have been developed for single-component systems.[23,26,28] A review of the literature on photochemical oxidant mixtures indicates that these relationships may justifiably be applied to mixtures as well as simple component systems.

There are five reports in the literature of human exposure data that may be used for comparative purposes.[1-5] Unfortunately, the conditions are not the same among the five reports. Concentration, HC/NO_x ratio, species of nitrogen oxide (NO), and duration of ultraviolet irradiation--while the same for most experiments in a group--differ from one set to another. In addition, each set of experiments used a different method for evaluating sensory irritation. In order to compare these data, four levels of irritation have been designated: (*1*) S = severe; (*2*) M = moderate; (*3*) L = light; and (*4*) N = none. These levels have been applied to transform the various scales used in the different sets of data to fit the four designations. In so doing, the investigators' indications as to the peak values that correspond to the indicated levels of severity of eye irritation have been used.

Table 2 present the results of the five sets of published data with our results in the last column for comparison. The HC/NO_x ratio, species of NO, and duration of irradiation are indicated for each set.

Initially there does not appear to be good correlation among these six sets of data; however much of the difference can be explained by examining the conditions of each set of experiments.

The HC/NO_x ratio is one source of variability. The optimum HC/NO_x ratio is 3:1. Depending on the hydrocarbon, a greater relative concentration of *N*-oxide (in sets 1 and 4[1,4]), could promote destruction of the sensory irritants as they are formed. In addition, the species of *N*-oxide can influence the irritation potential, especially when considered with the duration of ultraviolet irradiation. This is because NO must first be converted to NO_2 before irritants can be formed. This can explain why the results differ between sets. For example, if one is starting with ethylene and NO, 2 hr is not enough time, since ethylene is slow to react with NO_2 and the maximum sensory irritation effect is after 4 hr of irradiation.

All the sets of data show that 1, 3-butadiene is a severe sensory irritant. This is to be expected since one of the products of its photochemical reaction is acrolein, a very potent sensory irritant. The only author to use *n*-butane agreed with our results of no sensory irritation. Again, this is to be expected, since alkanes are nonreactive in photochemical processes.[1,24] The other three hydrocarbons yielded a variety of results among investigators. The conditions used by Heuss and Glasson[1] (Set 1) were the least ideal for maximizing sensory irritation, (e. g., NO_x excess, nitric oxide) and showed the lowest sensory irritation potentials for each gas. Schuck and Renzetti[2] (Set 2) presumably used an optimal HC/NO_x ratio, but also used NO and a shorter irradiation time. Their experiments also yielded low sensory irritation responses.

The use of propylene in the experiments reported here has generated the most potent sensory irritant mixtures of those tested. However, it takes a longer irradiation time before these mixtures produce a maximum sensory irritation. When ethylene was used, it again took longer to reach maximum potency. On a mole-for-mole basis, however, ethylene caused a much less severe sensory irritation than propylene.

The greater potency seen with propylene can be explained by the fact that unlike the other hydrocarbons tested, propylene produces a high concentration of peroxyacetyl nitrate (PAN).[1,16,17] PAN is known to be a much

Table 2.–Comparison of Eye Irritation Potentials under Various Experimental Conditions for Different Investigators

	Set One[1]	Set Two[2]	Set Three[3]	Set Four[4]	Set Five[5]	This Report
HC/NO_x	2/1	3-6/1-2	1/.4	5/2	3/1	3/1
N-oxide	NO	NO	NO_2	NO	NO_2	NO_2
Ultraviolet irradiation time	6 hr	2 hr	--	1 hr	2 hr	(to maximum response)
GAS						
1, 3-Butadiene	S	S	--	S	S	S (2–3 hr)
1-Butene	L	L	S	--	--	S (2–3 hr)
cis-2-Butene	L	--	M	M	--	S (2–3 hr)
Ethylene	N	L-N	L	--	S	M (4 hr)
n-Butane	N	--	--	--	--	N
Ethene	--	--	--	--	--	N
Propylene	L	L	N	--	M-S	S (4 hr)

NOTES:
-- = not reported.
S = severe.
L = light.
M = moderate.
N = none.

more potent sensory irritant than acrolein or formaldehyde, which are the main products formed from the other hydrocarbons tested.[1]

Referring back to the animal model based on the relationship between the mouse RD_{50} and the sensory irritation response in man, we would predict that photochemical oxidant mixtures made from the hydrocarbons listed in Table 1 would be intolerable to humans at the RD_{50} concentrations listed. It would also be predicted that discomfort from sensory irritation would result at levels one-tenth the RD_{50}. The results presented in Table 2 are consistent with this hypothesis.

In summary, it has been shown that an animal model system based on the reflex decrease in respiratory rate can be used as a bioassay to predict the sensory irritation to man of various photochemical oxidant mixtures.

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This investigation was supported by the National Institute of Environmental Health Sciences, Grant no. 5 R01-ES-00872.

Submitted for publication December 21, 1976; revised; accepted February 3, 1977.

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REFERENCES

1. Heuss, J., and Glasson, W. 1968. Hydrocarbon reactivity and eye irritation. *Environ Sci Tech* 2: 1109-16.
2. Schuck, E., and Renzetti, N. 1960. Eye irritants formed during photo-oxidation of hydrocarbons in the presence of oxides of nitrogen. *J Air Pollut Control Assoc* 10: 389-92.
3. Haagen-Smit, A. 1952. Chemistry and physiology of Los Angeles smog. *Ind Environ Chem* 44: 1342-46.
4. Stephens, E.; Darley, D.; Taylor, O.; and Scott, C. Photochemical reaction products in air pollution. *J Air Water Pollut* 4: 79-100.
5. Faith, W., and Renzetti, N. 1960. *Seventh Technical Progress Report*, Rep. no. 33. San Marino, Calif.: Air Pollution Foundation.
6. Faith, W., and Renzetti, N. 1960. *Sixth Technical Progress Report,* Rep. no. 30. San Marino, Calif.: Air Pollution Foundation.
7. Faith, W.; Renzetti, N.; and Rogers, L. 1957. *Automobile Exhaust and Smog Formation,* Rep. no. 21. Los Angeles, Calif.: Air Pollution Foundation.
8. Faith, W.; Hitchcock, L.; and Neiburger, M. 1955. *Second Technical Progress Report,* Rep. no. 12. Los Angeles, Calif.: Air Pollution Foundation.
9. Marcus, H. 1955. *First Technical Progress Report,* Rep. no. 4. Los Angeles, Calif.: Air Pollution Foundation.
10. Morriss, F., and Bolze, C. 1957. *Reactions of Auto Exhaust in Sunlight,* Rep. no. 19. Los Angeles, Calif.: Air Pollution Foundation.
11. Schuck, E. 1957. *Eye Irritation from Irradiated Automobile Exhuast,* Rep. no. 18. Los Angeles, Calif.: Air Pollution Foundation.
12. Schuck, E., and Doyle, G. 1959. *Photo Oxidation of Hydrocarbons in Mixtures Containing Oxides of Nitrogen and Sulfur Dioxide,* Rep. no. 29. San Marino, Calif.: Air Pollution Foundation.
13. Schuck, E.; Doyle, G.; and Endow, N. 1960. *Progress Report on the Photochemistry of Polluted Atmospheres,* Rep. no. 31.

San Marino, Calif.: Air Pollution Foundation.
14. Buchberg, H.; Wilson, K.; Jones, M.; and Lindh, K. 1963. Studies of interacting atmospheric variables and eye irritation thresholds. *J Air Water Pollut* 7: 257-80.
15. Cadle, R., and Magill, P. 1951. Study of eye irritation caused by Los Angeles smog. *Arch Ind Hyg Occup Med* 4: 74-84.
16. Dimitriades, B., and Wesson, T. 1971. *Reactivities of Exhaust Aldehydes,* RI 7527. Washington, D. C.: U. S. Department of the Interior, Bureau of Mines.
17. Dimitriades, B., and Wesson, T. 1972. Reactivities of exhaust aldehydes. *J Air Pollut Control Assoc* 22: 33-38.
18. Doyle, G.; Endow, N.; and Jones, J. 1961. Sulfur dioxide role in eye irritation. *Arch Environ Health* 3: 657-67.
19. Renzetti, N., and Bryan, R. 1961. Atmospheric sampling for aldehydes and eye irritation in Los Angeles smog–1960. *J Air Pollut Control Assoc* 11: 421-24, 427.
20. Stanford Research Institute. 1954. *The Smog Problem in Los Angeles County.* Los Angeles, Calif.: Western Oil and Gas Association.
21. Wilson, W.; Levy, A.; and McDonald, E. 1972. Role of SO_2 and photochemical aerosol in eye irritation from photochemical smog. *Environ Sci Tech* 6: 423-26.
22. Yeung, C., and Phillips, C. 1973. Estimation of physiological smog symptom potential from chemical reactivity of hydrocarbons. *Atmos Environ* 7: 551-59.
23. Alarie, Y. 1973. Sensory irritation by airborne chemicals. *CRC Crit Rev Toxicol* 2: 299-363.
24. Leighton, P. 1961. *Photochemistry of Air Pollution.* New York: Academic Press.
25. Finney, D. 1964. *Statistical Method in Biological Assay,* 2nd ed. Haddonfield, N. J.: Griffin Press.
26. Alarie, Y. 1966. Irritating properties of airborne materials to the upper respiratory tract. *Arch Environ Health* 13: 433-49.
27. Kane, L. 1976. Photochemical-oxidant induced sensory irritation: Development of an animal model system, presented at the *Fifteenth Annual Meeting of the Society of Toxicology,* Atlanta, Georgia.
28. Barrow, C.; Alarie, Y.; and Stock, M. A. 1978. A comparison of the sensory irritation response to chlorine and hydrogen chloride in mice. *Arch Environ Health* 32: 68-76.
29. Alarie, Y.; Barrow, C.; Kane, L.; and Oka, S. 1977. Predictions from an animal model of sensory irritation in man evoked by airborne chemicals. *Proceedings of First International Congress on Toxicology,* p. 21.

Exposure to Dust-Borne Bacteria in Agriculture. I. Environmental Studies

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ABSTRACT

In order to evaluate the exposure of agricultural workers to dust-borne bacteria, microbiological examinations of the air were performed in grain storing and processing plants and in animal houses. Large concentrations of viable microorganisms, ranging from 129.2 to 1289.9 thousands/m^3 of air, were found in the rooms contaminated with grain dust and much lower in those contaminated with flour dust (22.6 thousands/m^3). Bacteria predominated in the air of grain plants, whereas actinomycetes and fungi were less numerous. The most abundant bacteria were Gram negative rods of the species *Erwinia herbicola*.

Large concentrations of air-borne microorganisms were also found in different animal farms, reaching 225.5 to 595.4 thousands/m^3 in hatcheries and 7751.5 thousands/m^3 in a broiler house. *Staphylococci* were most frequently isolated and other common organisms were *Corynebacteria* and *Streptococci*. It was concluded that high exposure to dust-borne bacteria creates a hazard to agricultural workers.

INHALATION OF GRAIN DUST and other agricultural dusts of plant and animal origin can cause respiratory diseases, which are mainly due to the sensitizing action of microorganisms occurring in these dusts.[1,2,3] Therefore, studies on air-borne microflora at different agricultural plants, including both determination of concentration and species composition, should be considered as very helpful in the identification of causative agents of such diseases.[4] The papers on this subject published so far dealt mostly with air-borne microbes in animal farms, which are important, both from the medicine and veterinary standpoints. The concentrations of viable particles in the air (given in thousands/m^3 [thous/m^3]) estimated by different authors with the use of cultivation methods at various animal houses ranged: 16.0–273.3 in cow barns;[5-9] 70.6-1,146.2 in piggeries;[6,7,9,10] 8.3-141.3 in poultry hatcheries;[11-15] 279.0-300,000.0 in broiler houses;[16-19] and 1.4-247.2 in a poultry slaughterhouse.[20] Cocci and Enterobacteria were reported by the majority of the authors as the most common contaminants in this environment.[6,8,12,15,16,18,19] There have been only a few studies of air-borne microflora in other places of agricultural production, including grain processing plants. Fungi and thermophilic actinomycetes associated with farmer's lung disease[2,4] were of particular interest, but very little attention was directed to bacteria. Stallybrass[21] isolated pathogenic *Aspergillus* strains from the air of a modern mill. Lacey,[4,22,23] using cascade impactor microscopic